Age-related decline in the ability to decode emotional prosody: Primary or secondary phenomenon?

Short title: DECODING EMOTIONAL PROSODY IN OLD AGE.

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Abstract

Emotion processing deficits can cause catastrophic damage to a person's ability to interact socially. Whilst it is known that older adults have difficulty identifying facial emotions, it is still not clear whether this difficulty extends to identification of the emotion conveyed by prosody. This study investigated whether the ability of older adults to decode emotional prosody falls below that of young adults after controlling for loss of hearing sensitivity and key features of cognitive aging. Apart from frontal lobe load, only verbal IQ was associated with the age-related reduction in performance displayed by older participants, but a notable deficit existed after controlling for its effects. It is concluded that older adults may indeed have difficulty deducing the emotion conveyed by prosody, and that whilst this difficulty can be exaggerated by some aspects of cognitive aging, it is primary in origin.

Keywords: older adults, emotional prosody, social interaction, cognitive aging.

Introduction

Everyday communications require us to decipher the emotional intentions of others, to interact successfully, and maintain social competence. Deficits in emotional communication skills therefore impair the ability to interpret the emotional states of others and to behave in a socially appropriate manner (Trauner, Ballantyne, Friedland & Chase, 1996). The ability to interpret emotional cues plays an important role in maintaining successful relationships and healthy psychological functioning (e.g. Carton, Kessler & Pape, 1999). Disturbed emotion processing consequently has potential to cause catastrophic damage to a person's ability to integrate into society.

It is now reasonably well established that aging affects one's ability to identify the emotions conveyed by facial expressions (e.g. MacPherson, Phillips & Della Salla, 2002; McDowell, Harrison & Demaree, 1994), although consistent with age-related attentional biases away from negative facial expressions (Mather & Carstensen, 2003), age-related reductions in facial emotion identification skill may be more prevalent for sad or angry expressions (MacPherson, Phillips & Della Sala, 2002; Sullivan & Ruffman, 2004). In typical identification tasks, photographs of faces are presented in the middle of a computer screen, underneath which adjectives are displayed describing different emotions (happy, sad, angry etc.) (MacPherson et al., 2002; Phillips, MacLean & Allen, 2002). Participants are instructed to choose the adjective that best describes the emotion displayed in the photograph. In addition, older adults tend to give atypical ratings of facial expression intensity compared to young adults when viewing photographs of target facial expressions and rating how strongly each displayed various emotions. Using a 9 point Likert scale, Phillips and Allen (2003) observed that older adults rated some aspects of emotions portrayed in facial expressions as less intense than young adults. For instance, older adults perceived lower levels of intensity in sad and happy faces. However, others have observed *higher* intensity ratings of some facial emotions by older adults (sadness – McDowell et al., 1994). Age-related decline in recognition of facial expressions is also observed when participants are given matching tasks where two faces must be classified as displaying the same or different types of emotional expression (MacPherson, Phillips & Della Salla, submitted), or when asked which of two faces is more angry, sad or fearful (Sullivan & Ruffman, 2004). These latter findings suggest that age differences in decoding emotion may not be due to the complex decisions required in labeling tasks.

Current Emotional Prosody Literature

Facial expressions are not the only means by which we may determine someone's communicative intent. When presented with speech, various other cues are available, and *how* something is said may be just as important as *what* is said. The features of speech that code this suprasegmental information include intonation, amplitude, and tempo. These characteristics are termed prosody, and they serve two main functions: to convey linguistic information (e.g. stress prosody), and emotion. Where there is conflict of meaning between the emotions conveyed by lexico-semantic content and prosody (e.g. sarcasm), prosodic cues may provide a vital key as to the intended meaning.

In contrast to the growing literature on facial emotion comprehension deficits, much less is known about how older adults decode emotional prosody. The literature that does exist is somewhat inconsistent. According to Brosgole and Weisman (1995), the ability to decode emotional prosody reaches an asymptote at age 12 which is maintained until middle age (mid 40s), following which the ability declines until beyond age 65, where emotional prosodic processing resembles that of 3-6 year olds. In Brosgole and Weisman's study participants were presented with pre-recorded sentences and asked to indicate their response in a forced choice response paradigm, pointing to the drawing of the face displaying the corresponding emotion in one condition, and giving a verbal forced-choice response in the labeling condition. The early report from Allen and Brosgole (1993) highlighted evidence for age-related decline in emotional AND linguistic prosodic processing. In this study participants judged emotional prosody using the same paradigm as Brosgole and Weisman (1995). In the linguistic prosody task participants heard pre-recorded neutral commands, statements or questions. In the first condition they indicated their response by pointing to the corresponding picture of an exclamation mark, a question mark or a full stop. In the second condition they gave a verbal response. Age-related deficits in interpretation of both types of prosody suggest older adults may have fundamental problems processing prosodic elements as opposed to a specific difficulty using these cues to interpret emotion. However, whilst a report by Raithel and Hielscher-Fastabend (2004) also suggested older adults find it difficult to interpret emotional and linguistic prosody, their participants showed linguistic prosody interpretation deficits only in certain conditions. When semantic information was available to participants, older adults were no worse than younger adults at identifying whether a stimulus represented a question, statement or command, even when the syntactic content contradicted the pattern of intonation. When the semantic information was masked by low-pass filtering, older adults' performance fell significantly below that of young adults. Interestingly, in non-emotion language tasks such as running memory for speech, spoken word recognition and syntactic parsing, older adults seem to rely more than young adults on prosodic information, and when it is available, their performance is more comparable to that of young adults (Wingfield, Lahar & Stine, 1989; Wingfield, Lindfield & Goodglass, 2000; Wingfield, Wayland & Stine, 1992).

Questions concerning the fundamentality of *emotional* prosodic processing deficits in older adults also arise from the role of lexico-semantic content and its complexity within test stimuli. Orbelo, Testa and Ross (2003) examined the ability of older adults to decode the emotional prosody in stimuli in which verbal content was progressively reduced, indicating their response by selecting the corresponding facial emotion/written label pair. They found older adults exhibited the biggest emotion identification dysfunction for asyllabic (the expression ‘aaaaahhhhh’) and monosyllabic stimuli (compared to whole words) and reasoned the more older adults rely on prosodic cues alone, the bigger their deficit. This interpretation was seemingly supported by the results of their second experiment in which participants heard pairs of stimuli from the identification task that had been filtered to create ‘pure’ prosody stimuli, and judged whether the emotions conveyed in each were the same or different. However, this scenario is not ecological; in everyday life we are rarely faced with prosodic information in the absence of semantic information. Indeed, an alternative explanation of the results is provided by Orbelo et al. themselves, who suggest purer prosodic stimuli may be more difficult to interpret because they are more ‘unnatural’.

Whilst the results of their second experiment led Orbelo et al. to conclude that the *absence* of lexico-semantic information degraded the performance of older adults, Kiss and Ennis (2001) proposed that the *presence* of concurrent semantic information would degrade older adults’ ability to interpret emotional prosody. Their stimuli consisted of neutral sentences recorded in different emotional tones of voice, and nonsense versions of these sentences which preserved phonemic features of the original sentences and were spoken in the same emotional tones, but in which the words had no recognised lexico-semantic meaning. Participants indicated the emotion conveyed via tone of voice, by pointing to the appropriate word on the response card. Kiss and Ennis’ results did not support their hypothesis, but since the lexico-semantic content was neutral, lack of conflict between information conveyed by lexico-semantic and prosodic content may not have caused enough interference to degrade performance. It may be that concurrent semantic information only degrades emotional prosodic processing in older adults when lexico-semantic information conflicts with that provided by prosody. Interestingly however, Thompson, Aidinejad and Ponte (2001) have shown that the ability of older adults to recall the emotion portrayed in a theatre scene accompanied by facial or prosodic emotion incongruent to its content, was influenced by facial information more than prosodic emotion, whereas young adults' performance did not differ according to the source of conflicting emotional information. In summary, the result of studies performed so far in older adults is that we do not know very much at all; findings conflict and there are many questions surrounding the fundamentality of this phenomenon.

Theoretical Doubts

In addition to queries raised by current literature, there are theoretical reasons to cast doubt on emotional prosodic processing deficits. 'Use it or lose it' theories (e.g. Swaab, Dubelaar, Hofman, Scherder, van Someren & Verwer, 2002) suggest that if we continue to remain active and perform certain cognitive functions as we age, neuronal function and survival may not be compromised (in contrast to 'wear and tear' theories), and some cognitive functions may not decline. Some have gone further and proposed that behaving this way builds up a 'cognitive reserve' enabling some people to cope with cognitive effects of abnormal ageing better than others (Scarmeas & Stern, 2003). We might predict that if an older adult remains engaged in society, and is continually exposed to social interactions, then since decoding emotional prosody is an integral part of social interactions, this function will not inevitably decline. In other contexts, a lifetime's practice at a task would be seen advantageous and could improve performance. There is evidence that certain aspects of emotional processing do improve with age, including the ability to regulate emotion (Gross, Carstensen, Tsai, Götestam-Skorpen & Hsu, 1997).

The second reason one might question the existence of age-related emotional prosodic processing deficits, concerns the oversight that with one exception (Orbelo, Grim, Talbott & Ross, 2005) none of the previous studies has considered the influence of co-occurring cognitive dysfunction. Emotional prosodic processing deficits may be caused by and secondary to, other primary age-related dysfunctions. Clues are available in the facial emotion processing literature, but results have been equivocal. Whilst MacPherson et al. (2002) demonstrated facial emotion recognition deficits disappeared when memory was a covariate, and most of Phillips and Allen's (2004) age-related deficits were explained by differences in anxiety, depression and IQ, Sullivan and Ruffman (2004) demonstrated facial emotion recognition deficits were independent of IQ. Orbelo et al. (2005) claim that the performance of older adults was not predicted by hearing loss and was only marginally predicted by scores on the Repeatable Battery for Assessment of Neuropsychological Status or the Stroop task. However, low scores on this test battery are not exclusively indicative of age-related decline (Beatty, Mold & Gontovsky, 2003; Dickerson, Boronow, Stallings, Origoni, Cole & Yolken, 2004; Randolph, Tierney, Mohre & Chase, 1998). Whilst Kiss and Ennis (2001) noted the extent of emotional prosodic processing deficits in their older adults was similar to the extent of memory deficits, they made no attempt to investigate the relationship. The results of Orbelo et al. (2005) currently require replication and a range of potential confounding factors remain to be explored.

Potential Mediators

The current study set out to explore five key potential mediators of age-related decline in the ability to decode emotional prosody:

Frontal Lobe Load: One theory of cognitive aging supposes much age-related cognitive decline can be explained by frontal lobe deterioration (West, 1996), particularly prefrontal cortex (Tisserand & Jolles, 2003). Performance on a 'frontal lobe' task would therefore be more likely to decline with age than a task whose performance was less dependent on the frontal lobe. General working memory processes are supported by prefrontal cortex (Cabeza & Nyberg, 2000). Thus a task that differed in working memory demand could be used to assess whether age-related deficits in the corresponding cognition appeared only in tests of that cognition which engendered a high frontal lobe load (FLL).

Hearing Loss: Hearing loss is known to affect speech perception in older adults, from higher-level cognitive processes, to lower-level perceptual processes (Schneider, Daneman & Pichora-Fuller, 2002). Older adults are poor at judging sound duration (Ostroff, McDonald, Schneider & Alain, 2003), are badly affected by background noise (Schneider, Daneman, Murphy & Kwong-See, 2000), and their hearing sensitivity loss also affects their ability to use linguistic prosody in word recognition (Wingfield et al., 2000). Hearing loss in older adults therefore has potential to artificially inflate emotional prosodic processing deficits.

IQ: Decline in IQ could deleteriously affect many cognitions and one could predict emotional prosodic processing would similarly be degraded by age-related IQ deficits. Emotion recognition deficits are prevalent in low IQ populations, and these deficits may contribute to their social adaptation problems (Moore, 2001). Numerous intellectual functions are associated with age, often in a curvilinear fashion reflecting rapid growth during formal education and slow decline thereafter (Salthouse, 1998). Age-related decline in IQ between youth and old age therefore needs taking into account.

Depression: The association between depression and emotion could, in a depressed person, affect how they process emotional prosody. This ability could be skewed by the associated negative bias (Kan, Mimura, Kamijima & Kawamura, 2004), or impaired more generally by the associated reduction in processing resources (Den Hartog, Derix, Van Bemmel, Kremer & Jolles, 2003). It has been claimed that depression is the most common mental health problem of older people (Baldwin, 2000; Blazer, 2003), and that rates of depression are higher in older adults than in young adults (Mecocci, Cherubini, Mariani, Ruggiero & Senin, 2004). Unless attempts are made to separate the effects of depressed mood and ageing, any age-related reduction in ability to decode emotional prosody could appear artificially exaggerated. Whilst participants who gave a self-report of psychiatric disorder (including depression) were excluded from the study, evidence suggests that there is a significant group of older adults with depressive symptoms who do not meet DSM-IV criteria for major depression (Beck & Koenig, 1996). Thus further attempts to separate the effects of depressive symptoms and old age are required.

Verbal Working Memory: ***Verbal*** working memory is crucial for sentence comprehension (Caplan & Waters, 1999), even in tasks that do not deliberately incorporate high FLL. "Our comprehension of the complex… …information conveyed in spoken language often appears to lag behind the sensory input, so that we have the experience of laboring with interpretation of the meaning of a sentence… …some time after the speaker has finished speaking" (p 201, Gathercole & Baddeley, 1993). If verbal working memory is needed to enable listeners to manipulate or rehearse speech information until its meaning is decoded, individuals with poor verbal working memory might struggle to decode emotional prosody. Evidence already exists that age-related verbal working memory deficits affect speech comprehension (Wingfield, 1996; Zurif, Swinney, Prather, Wingfield & Brownell, 1995).

Questions of Interest

This study aimed to investigate the relationship between these factors and emotional prosodic processing in older adults. The following questions were of especial interest: Does the existence of emotional prosodic processing deficits in healthy older adults depend on FLL? Do healthy older adults still demonstrate emotional prosodic processing deficits after controlling for hearing sensitivity, IQ, depression, and verbal working memory?

Methods

Following procedures specified by the University of Reading's Ethics and Research Committee, this study was independently scrutinized and granted ethical approval.

Participants

40 older participants (16 males, 24 females; aged 70.5 $\pm$ 5.8 years, minimum 61 years, maximum 83 years) were recruited from a database of older adult volunteers maintained by the University of Reading. 40 young adults (6 males, 34 females; aged 19.6 $\pm$ 1.7 years, minimum 18 years, maximum 27 years) were recruited from the undergraduate panel operated by the School of Psychology. Volunteers were excluded if they had uncorrected vision or hearing difficulties, a history of psychiatric or neurological disorder, a history of drug or alcohol abuse, any serious head injuries or long periods of unconsciousness. The two groups did not differ in number of years education ($t(78)=0.88$, $p=0.383$) or average weekly alcohol consumption ($t(78)=1.39$, $p=0.169$).

Experimental Paradigms and Procedures

Four preliminary assessments were performed first (in counterbalanced order) to derive data on dysfunctions that might confound age-related emotional processing deficits. Before each assessment, checks ensured participants could reach response keys comfortably, that they understood all instructions, and that they could hear the auditory stimuli clearly.

Hearing loss: According to French and Steinberg (1947), the most important speech frequencies range between 500 Hz and 2 KHz. Hearing loss for these frequencies could seriously attenuate the ability to comprehend speech. Accordingly, a Kamplex KS8 screening audiometer was used to assess participants' hearing loss in dB (HL) (compared to norms from BS EN 60645 and BS EN ISO 389), at 500 Hz, 1 kHz and 2 kHz. A 'pure tone average' (PTA) was derived for each ear, by calculating mean hearing loss at these frequencies.
Measure used in analyses: Mean PTA across both ears ('combined PTA').

IQ: The National Adult Reading Test (NART: Nelson, 1982) is an approximation of IQ which comprises 50 irregularly spelt words, whose pronunciation cannot be predicted from simple letter-sound correspondences. In the normal adult population, level of reading ability is closely related to general intellectual level (Nelson & McKenna, 1975). For example, Crawford, Stewart, Parker, Besson and De Lacey (1989) used a full-length WAIS and reported that the NART explained 66% of IQ variance in a census matched sample of healthy adults. Since performance is not affected by cognitive impairment associated with early dementia (e.g. Crawford, Deary, Starr & Whalley, 2001), its administration dissected normal age-related changes in IQ, prior to and unconfounded by, subclinical/undiagnosed dementia-associated declines. A self-paced form was administered whereby words were presented centrally onscreen, participants read them aloud and then pressed the space bar to move on.

Measure used in analyses: Predicted verbal IQ (‘verbal IQ’).

Depression: To assess severity current depressive symptoms, Beck’s Depression Inventory (BDI: Beck, 1987) was administered. Participants were given the questionnaire, asked to read each group of statements carefully, and circle the number next to the statement that best described the way they had felt in the past week. The BDI was scored by summing the severity ratings for participants’ responses to the 21 questions.

Measure used in analyses: Total BDI score (‘BDI’).

Verbal Working Memory: To test for general working memory skills, but retain relevance to verbal tasks, Daneman and Carpenter’s (1980) reading span task was administered. Daneman and Carpenter developed this test as a means of assessing people’s ability to perform active processing of a stimulus while simultaneously buffering other information in working memory. Its use as a measure of central executive functioning is based on the idea that test performance reflects the total amount of attentional resources that can be allocated to information storage and manipulation (Just & Carpenter, 1992). The task contains 5 sets of two sentences, 5 sets of three, 5 sets of four, 5 sets of five, and 3 sets of six. Each sentence was presented on screen. Participants read each aloud, beginning as soon as it appeared, and pressed the space bar when they were ready to move on. At the end of each set participants were instructed to say as many of the last words of the sentences as they could, preferably in order, and without saying the last word first. They were advised that the test began with two sentences in a set and that the sentences per set would increase, but that they would be warned before each switch. If a participant failed 3 out of the 5 sets at a level the test was terminated. Participants’ reading span was defined as the level at which a participant was correct on three out of the 5 sets, however, if a participant was correct on only two, he or she was given a credit of 0.5, e.g. correct on two out of the five 3 sentence sets = score of 2.5. In this example if they were only correct on one out of five, they were assigned the score of 2. Measure used in analyses: ‘Reading span’.

Emotional prosody task:

To manipulate FLL, differing levels of working memory demand were built into the task conditions. N-back tasks are believed to engage working memory in several respects, including: (i) encoding a stimulus into working memory; (2) maintenance of this representation in working memory despite subsequent presentation of additional stimuli; (3) retagging each still-relevant representation with a new positional code to reflect the updating of working memory that happens as each new stimulus appears (Postle, Desposito & Corkin, 2005). A recent meta-analysis by Owen, McMillan, Laird & Bullmore (2005) confirms that activation of lateral prefrontal cortex in the frontal lobe is a robust finding across studies, indicating the validity of this task as a test of frontal lobe function. Furthermore, increased working memory demand from the 0-back through to 2-back conditions results in corresponding increases in prefrontal cortex activation (Jaeggi et al., 2003), suggesting that manipulating working memory demand in an N-back style task would be an effective means of manipulating the FLL of an emotional prosody decoding task.

Stimuli in the emotional prosody decoding task were pre-recorded sentences of a consistent style and format (in the third person, and involving a subject and an action), describing neutral scenarios (e.g. ‘The cheque was paid into the bank’). Prior to recording, a bank of these written sentences was recorded by an experienced, male phonetician (AC) in both a happy and sad style of emotional intonation. Sentence length varied from approximately 2 s to 4 s, although the happy and sad prosody recordings of each sentence did not differ in mean sentence duration ($t(59) = 0.887$, $p = 0.394$). Using a phonetician to record the sentences enabled accurate and consistent portrayal of emotional intonation, since they are more able to record the sentences formulaically, controlling both pitch direction, and pitch height and range (see Scherer, 1986 for a discussion of the problems encountered when using actors to portray emotions). Audiocassette recordings were then digitised at 22 kHz/16 bits (see Mitchell, Elliott, Barry, Cruttenden & Woodruff, 2003). There were no differences in mean or peak amplitude between the happy and sad prosody sentences (($t(59) = 0.418$, $p = 0.677$) and ($t(59) = 0.326$, $p = 0.745$) respectively).

In each condition of the emotional prosody N-back style task, twenty stimuli were randomly selected from the suite of 120 potential stimuli and auditorily presented every 4.5 s. Participants were required to identify the emotion conveyed by intonation, pressing 1 if they thought a sentence was spoken in a happy tone of voice and 0 if they thought it was spoken in a sad tone. Within each condition half the sentences were spoken in a happy tone of voice and half in a sad tone of voice (in random order). In accordance with the procedure for most N-back tasks, in the 0-back condition of the emotional prosody decoding task (baseline performance) participants were instructed to indicate their response to the current sentence. In the 1-back condition they indicated their response to the previous sentence and in the 2-back condition they indicated their response not to the previous sentence, but to the one before that. These three conditions were counterbalanced across participants. During each condition onscreen cues reminded participants of the response rule. Cards at the top of the keyboard reminded participants of the response keys.

Statistical Analyses

Performance accuracy (% of stimuli for which a correct response given) was derived for each participant, for each FLL level. An ANCOVA was performed examining the main effects of age (between subject factor with 2 levels: young or old) and FLL (within subject factor with 3 levels: 0-back, 1-back, 2-back), and the interaction. Standard checks ensured there were no violations of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of covariates. Initially all four covariates were entered into the model (1st ANCOVA): combined PTA, verbal IQ, BDI, and reading span. Any that did not demonstrate a significant relationship with the dependent variable whilst controlling for independent variables, were then removed and the analysis re-run incorporating only significant covariates (2nd ANCOVA). Only verbal IQ received significant statistical support for its inclusion. Where necessary, the ANCOVA was followed with planned contrasts and further analyses, to determine the source of statistical significance.

The lack of covariate effects in this initial analysis prompted a reconsideration of the data. It was noticed that whilst the chronological age range of young adults was comparatively narrow (s.d. 1.7), there was a much larger range of ages amongst older adult participants (s.d. 5.8). Whilst their exact composition can vary, researchers identify subgroups of "older adults" as "younger old" (ages 65-75), "older-old" (ages 75-85), and "oldest old" (ages 85+) (Suzman, Willis & Manton, 1992). Older adult participants in this study ranged in age from 61 years old to 83 years old, and were therefore composed of a mixture of ‘younger old’ and ‘older old’. Since cognitive skills can be further reduced in the older- and oldest-old compared to the younger-old (e.g. Chandler et al., 2004; McGinnis & Zelinksi, 2003), the potential complication of within-group age effects needed to be addressed. The data were therefore reanalyzed (3rd ANCOVA) (i) to assess whether the effects of older adult performance confounds were ‘diluted’ when applied across the full range of ages of older adult participants, and (ii) to discover whether there were between-group differences in the relationship between performance accuracy and chronological age of participants within a group. To this end, a new custom model ANCOVA was run to assess the effect of FLL and the four original covariates, but now also including chronological age as a covariate, and interactions with the new covariate.

Results

Table 1 summarizes descriptive statistics of the experimental task, Table 2 summarizes the covariates. Results are reported as significant for p equal to or less than 0.05. After adjusting for verbal IQ, the main effect of FLL was not significant ($F(2,77)=1.70$, $p=0.19$), but the main effect of age was ($F(1,77)=21.46$, $p<0.001$); older adults were less accurate than young adults. However, there was also a significant interaction between FLL and age ($F(2,77)=5.25$, $p<0.01$), with greater performance accuracy in young vs. old participants at all three levels (0-back: ($F(1,77)=1.39$, $p<0.05$; 1-back: ($F(1,77)=23.48$, $p<0.001$; 2-back: ($F(1,77)=14.37$, $p<0.001$). Whilst the effect size of the between-group difference was low in the 0-back condition (eta squared = 0.05), it was noticeably stronger for heavier FLL (eta squared for the 1-back and 2-back conditions were 0.23 and 0.16 respectively). In the supplementary analyses, chronological age within a group did not covary significantly with performance accuracy ($F(1,66)=0.24$, $p=0.63$), and there were no significant interactions between age group and any of the six covariates; each exerted a similar effect on performance accuracy in both age groups ($p=0.35$ to 0.99).

Table 1 and Table 2 about here

Discussion

Emotional Prosodic Processing Deficits

The results suggest that the ability of healthy older adults to decode emotional prosody is reduced relative to that of healthy young adults (all ANCOVAs), although this difficulty does not appear to worsen with further advances in age (supplemental ANCOVA including chronological age). Few measures of cognitive and perceptual aging were associated with the age-related emotional prosodic processing deficits; only FLL and verbal IQ (initial ANCOVA with all covariates). Furthermore, when the effects of those that were associated were controlled, the deficits remained significant (ANCOVA with only the significant covariates). In keeping with Orbelo et al. (2005), these findings suggest that the difficulty older adults have decoding prosody is primary, and not secondary to some other aspect of cognitive or perceptual aging. Indeed, Orbelo et al. (2005) demonstrated that poor comprehension of emotional prosody was only related to poor performance on a memory test from their test battery, and only in older adults at risk of Alzheimer's disease. However, surveying the abilities of increased numbers of older adults may be necessary to fully rule out the absence of links to the hypothesized cognitive mediators. The gender split of the young and old participant groups differed somewhat, however, whilst reports exist of qualitative gender differences in decoding emotional prosody (e.g. Schirmer, Kotz & Friederici, 2002), there are no general reports of quantitative accuracy differences.

Although it was predicted that age-related decline in emotional prosodic processing might be partially mediated by age-related decline in IQ, no such association was observed in the current study. However, it is of increasing concern in the study of age-related cognitive decline whether such changes represent uni-dimensional processes or multi-dimensional processes in which specific cognitions decline in different ways (Hess & Blanchard-Fields, 1996). In the study of intelligence, one of the most common distinctions is that between fluid and crystallised intelligence. In older adults, it seems that only fluid intelligence declines with age (Anstey & Low, 2004). Fluid intelligence represents the ability to reason and solve problems in novel or unfamiliar situations. It increases gradually as the nervous system matures, then levels off in adulthood, followed by a steady decline. 'Crystallised' abilities involve accumulated knowledge and expertise. They increase during the lifespan and are less affected by old age. Hence there are two possible interpretations of the null finding: (i) Age-related decline in decoding emotional prosody is not mediated by age-related decline in IQ, or (ii) Whether age-related decline in decoding emotional prosody is mediated by IQ depends on the type of IQ test used (and whether it assessed fluid or crystallised abilities). Only further study with varied IQ assessments can distinguish between these possibilities.

Whilst age-related emotional prosodic processing deficits in this study were not related to performance accuracy on most of the supplementary tasks, their deficit was worsened by increased FLL. The frontal lobe theory of cognitive aging (e.g. West, 1996), purports that the frontal lobes are particularly vulnerable to age-related deterioration, and that cognitions that depend on the frontal lobes are particularly at risk. Performance of older adults during emotional prosody identification tasks is more likely to be impoverished on tasks engendering a high frontal lobe demand (whether knowingly incorporated or not), it can confound accurate conclusions of age-related decline. Such tasks, whilst focusing on identification of emotional prosody, may require greater recruitment of executive functions e.g. maintenance of material 'on-line', selective attention, and decision making, to process the prosodic information, screen out unnecessary information, decide on one's interpretation and retrieve the appropriate response. We can surmise that unintentional between-study differences in frontal lobe demand could cause discrepancies in detection of emotional prosody identification deficits in older adults. Whilst high FLL exaggerated the deficit displayed by older adults, a clear deficit was also present in the 0-back baseline condition.

The fundamental emotional prosody identification deficit in older adults may be primary, but these deficits may be increased by additional phenomena secondary to selected frontal lobe based decline. Clearly, on its own, the frontal lobe theory is an incomplete explanation.

Some Implications

This study assessed age-cohort differences in one of the most important means of communication. The findings are significant because they provide insight that these age-related changes are part of a specific decline in emotional prosodic processing ability rather than a by-product of distinct cognitive dysfunctions. As such, the rationale of tackling concurrent cognitive/perceptual dysfunctions to treat associated secondary deficits may have little effect. A specific age-related emotional prosodic processing deficit implies service providers may need to re-consider how to communicate more effectively with some of their older adult clients, taking account of the potential that emotional signals they thought they were conveying might not be accurately interpreted. It is important to note that older adults in this study did not suffer a psychiatric or neurological disorder. Therefore reduced ability to decode emotional prosody is not necessarily restricted to small subsets of older adults. Reports exist of training programs that have successfully improved participants' ability to decode facial emotions (Grinspan, Hemphill & Nowicki, 2003; Silver, Goodman, Knoll & Isakov, 2004). It may be similarly possible to devise programs to improve participants' ability to decode emotional prosody. Indeed 'elderspeak' - a distinctive speech pattern displayed by those who spend time communicating with older adults that enhances normal intonation and stress – improves dialogue comprehension in older adults, albeit in use of *non*-emotional prosody (Cohen & Faulkner, 1986). Programs which coach older adults affected by this difficulty in how to better communicate and interpret emotional intentions, could only improve the effectiveness with which they integrate into society.

Potential Mediators & Future Studies

The results of this study provide clearer evidence that the ability of older adults to interpret emotional prosody is poorer than that of young adults. Whilst the ability to interpret facial emotion also seems to decline with age, in many other respects the emotional processing abilities of older adults are comparable to those of young adults. Older adults do not differ from young adults in their self-reports of emotion intensity (Carstensen, Pasupathi, Mayr & Nesselroade, 2000), in emotion-specific patterns of autonomic nervous system response (Levenson, Carstensen, Friesen & Ekman, 1994), nor in their spontaneous production of facial expressions (Tsai, Levenson & Carstensen, 2000). In view of the stark contrast between age-related effects on these two groups of abilities, future research needs to establish what causes the age-related decline in ability to decode emotional prosody.

Cognitive Mechanisms:

In the facial emotion literature, older adults have difficulty identifying and discriminating between emotions. Whilst labeling tasks incorporate additional cognitive processes to that being investigated, non-labelling tasks may provide a ‘purer’ assessment, free from complications such as retrieval of response labels. Poorer older adult performance in both tasks increases the generalisability of facial emotion deficits, hinting that they may be fundamental, but it is not yet possible to assess whether this is true for prosody. The increasing performance gap between young and old participants with higher FLL suggests that increasing task difficulty can accentuate age-related decline. One might predict less age-related decline in a discrimination type prosody task. Separation of external and external response to emotional prosody in older adults may be difficult without objective response measures (e.g. skin conductance). However, one avenue might be to examine older adults’ confidence judgments of their responses. High confidence judgments with low accuracy, would suggest lack of awareness of poor performance and perhaps add weight to claims of a primary origin. If the reverse were true, normal internal or 'pure' skills are of limited use if someone cannot communicate their knowledge externally. Finally, it would also seem sensible to ascertain whether older adults' ability to decode emotional prosody varied according to emotion as it seems to for facial expressions. If older adults' difficulty decoding emotional prosody were universal across the basic emotions (Ekman, 1999), it would lend further support to the suggestion that this age-related decline represented a primary phenomenon, driven by bottom-up influences.

Social & Neural Mechanisms:

The links between emotional prosody decoding skill, relationship well-being and psychological health (Carton et al., 1999), suggest social difficulties or mediators might be a fruitful avenue of investigation. Indeed, for many older adults psychosocial adversity can be a significant component of the ageing experience (Alexopoulos, 2005). A second avenue is delineation of functional and structural neuroanatomy. Age-related cortical thinning has already been demonstrated in regions known for their importance in emotional processing, over and above global cortical thinning (Salat et al. 2004). There are currently no published reports of the functional neuroanatomy of emotional prosodic processing in older adults, however, attempts have been made by Gunning-Dixon et al. (2003) and Iidaka et al. (2002) to discover the brain regions recruited by older adults when processing *facial* emotions. In the Gunning-Dixon et al. study older adults recruited different cortical networks relative to those recruited by young participants, including increased prefrontal activation in the older adults, whereas in the Iidaka et al. study, older adults' differential brain activity relative to young adults varied according to emotion valence.

In young adults neuroimaging highlights the right lateral temporal lobe as mediating emotional prosody decoding (Buchanan et al., 2000; Mitchell et al., 2003). We might therefore expect to observe reduced right lateral temporal lobe activity in older adults identifying prosodic emotion. These thoughts are echoed by others who have also suggested age-related emotion decoding deficits are associated with irregular right hemisphere activity, but who propose more general ‘right hemisphere decline’ hypotheses (Orbelo et al., 2003), or lean on theories associating right hemisphere with all emotional processing, ignoring the rich variability in neuroanatomy of facial emotion processing (McDowell et al., 1994; Moreno, Borod, Welkowitz & Alpert, 1990). Decoding emotional prosody is a right-lateralised function, but nonetheless a language function (Mitchell & Crow, 2005). Whilst researchers may study emotional prosody in isolation for experimental reasons, language functions are rarely used in isolation by the speaker. Considering that integrity of language functions is dependent on efficient cross hemisphere integration (Cook, 2002), a second focus should be contributions from cross hemisphere integration. Reports of decreased auditory interhemispheric integrity (Bellis & Wilber, 2001) and abnormal lateralisation of other cognitive functions with age (Cabeza, 2002) can only strengthen this as a candidate for further study.

In summary, this study has clarified that older adults have difficulty decoding emotional prosody even after considering the effects of other aspects of sensory and cognitive ageing. Further research needs to ascertain the generalisability of this finding and the underlying causes.

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Table 1

Descriptive statistics concerning the emotional prosody task.

Frontal Lobe Load	**Older Adults**		**Young Adults**	
	Mean % Accuracy	**Standard error**	**Mean % Accuracy**	**Standard error**
0-back condition (baseline performance)	79.5	2.7	86.3	1.3
1-back condition	70.0	3.6	90.1	1.6
2-back condition	57.9	3.1	74.1	2.5

Table 2

Descriptive statistics concerning the potential covariates

Potential Covariate	**Participant Group**			
	Older Adults		**Young Adults**	
	Mean	**Standard Error**	**Mean**	**Standard Error**
Combined Pure Tone Average (dB)	24.4	2.44	15.8	1.09
Verbal IQ	119.9	0.78	121.3	0.60
Beck's Depression Inventory	6.6	0.53	5.9	0.76
Reading Span	3.0	0.12	2.9	0.13